UF | IFAS
UNIVERSITY of FLORIDA

CENTER FOR AQUATIC AND INVASIVE PLANTS

Herbicides in Lake Sediments:
Understanding Herbicide Fate

Jason Ferrell, Mark Hoyer, Bill Haller
UF/IFAS Center for Aquatic and Invasive Plants

UF | IFAS UNIVERSITY of FLORIDA — CENTER FOR AQUATIC AND INVASIVE PLANTS

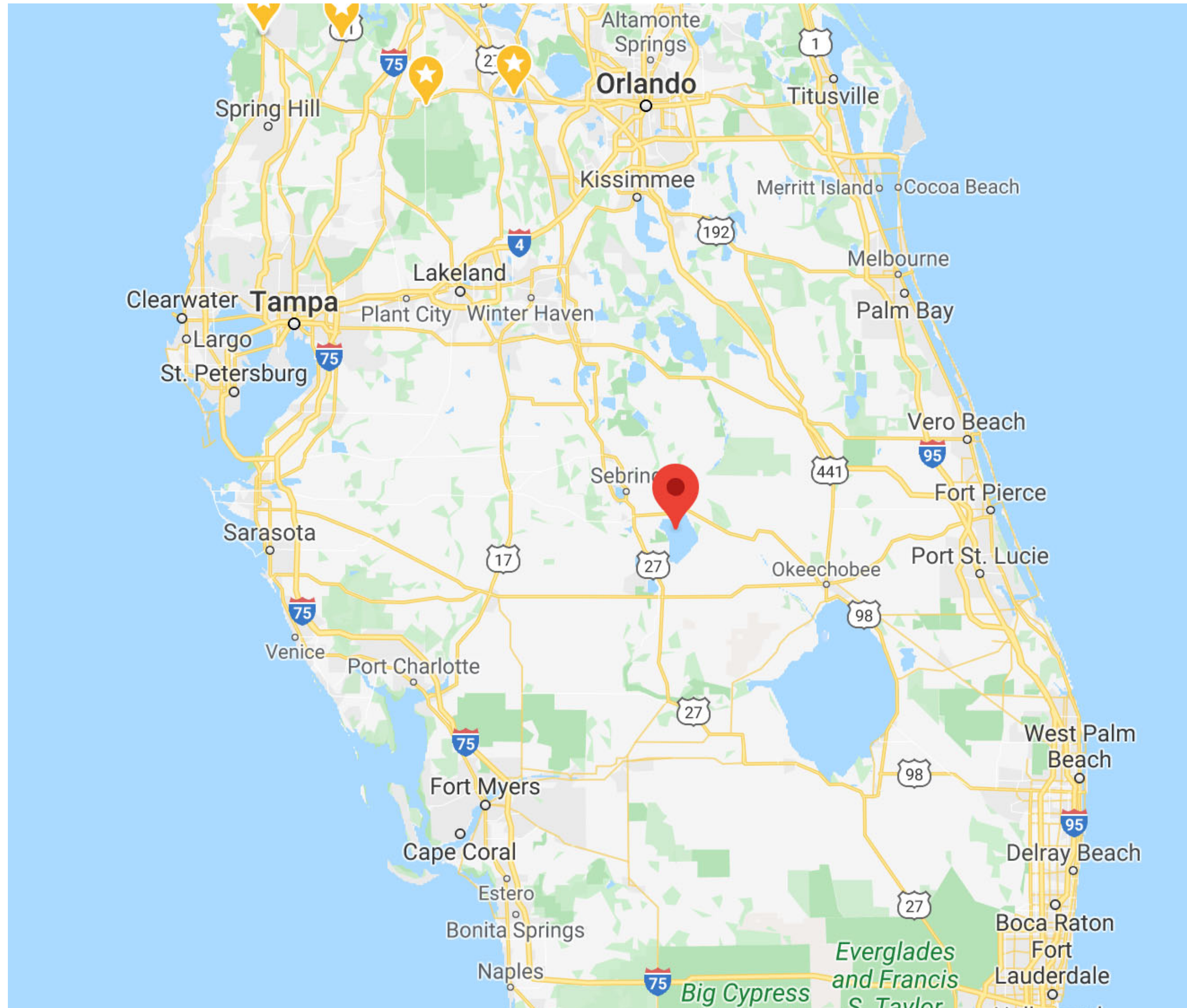
Legacy herbicides in lake sediments:

A Stakeholder Driven Approach

Jason Ferrell, Mark Hoyer, Bill Haller – UF/IFAS

Lake Istokpoga, FL

- 27,000 acre lake in south FL
- Average depth: 4 ft
- Excellent fishery
- Historically infested with hydrilla



UNIVERSITY of FLORIDA | AND INVASIVE PLANTS

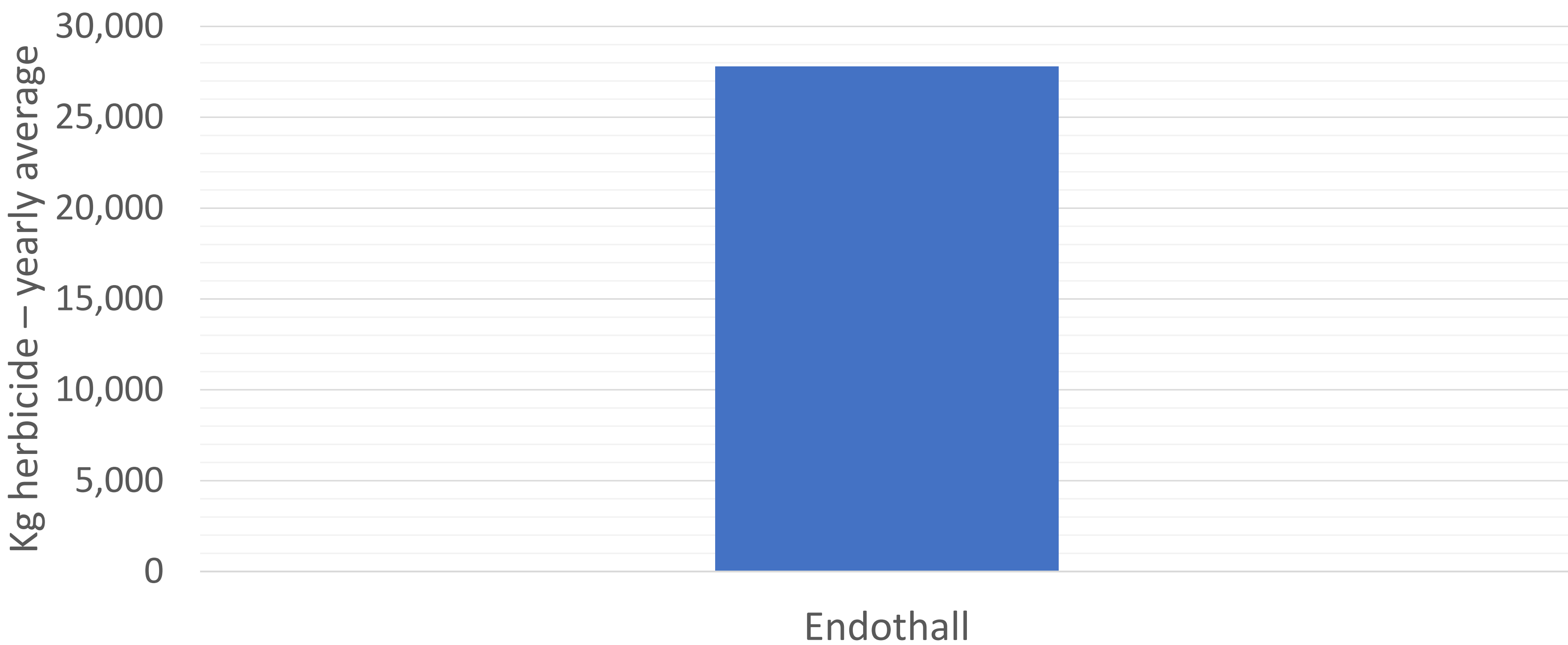
Hydrilla infestations

- In early 1990s, over 20,000 acres of hydrilla on the lake
- Aggressive, lake-wide, management instituted

- However, anglers have become convinced that hydrilla, is essential for a healthy fishery
- More recently, hydrilla is spot-treated

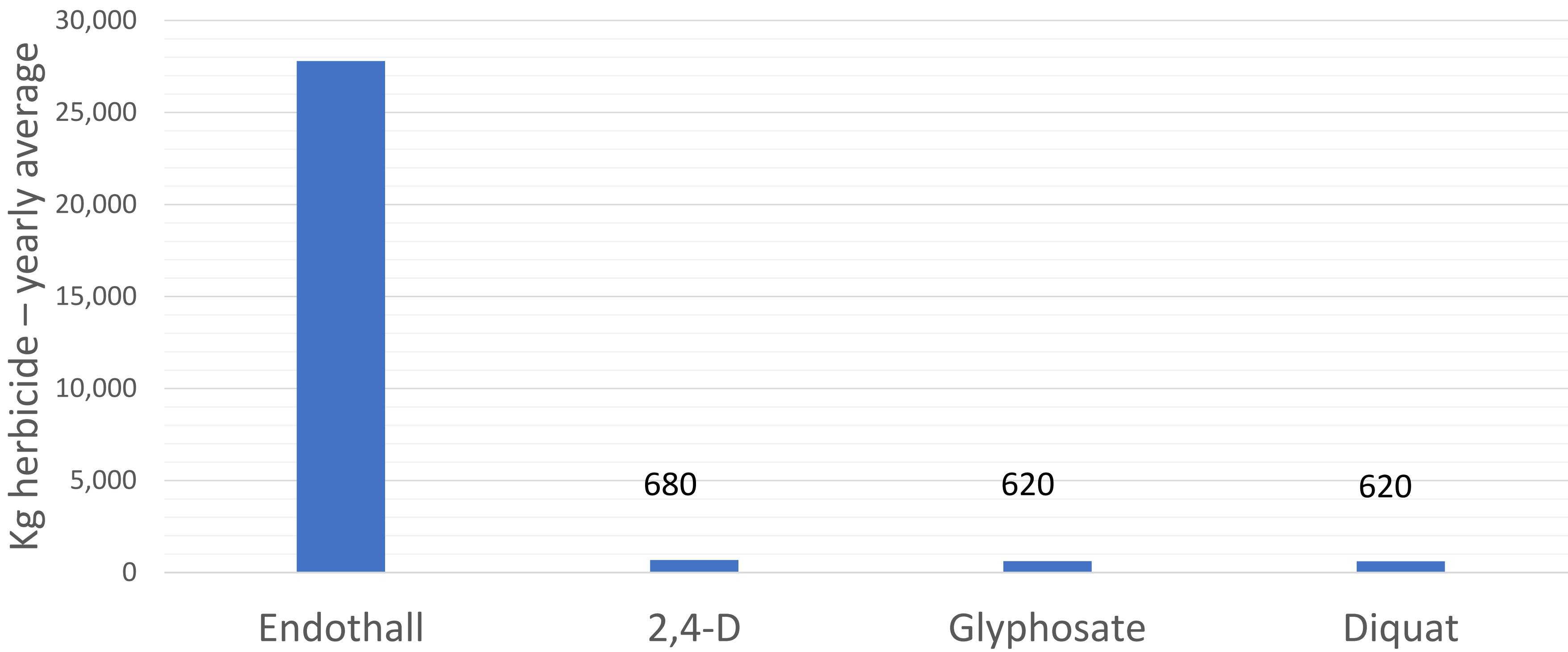
UF|IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

Herbicide use – 10-year average



UF IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

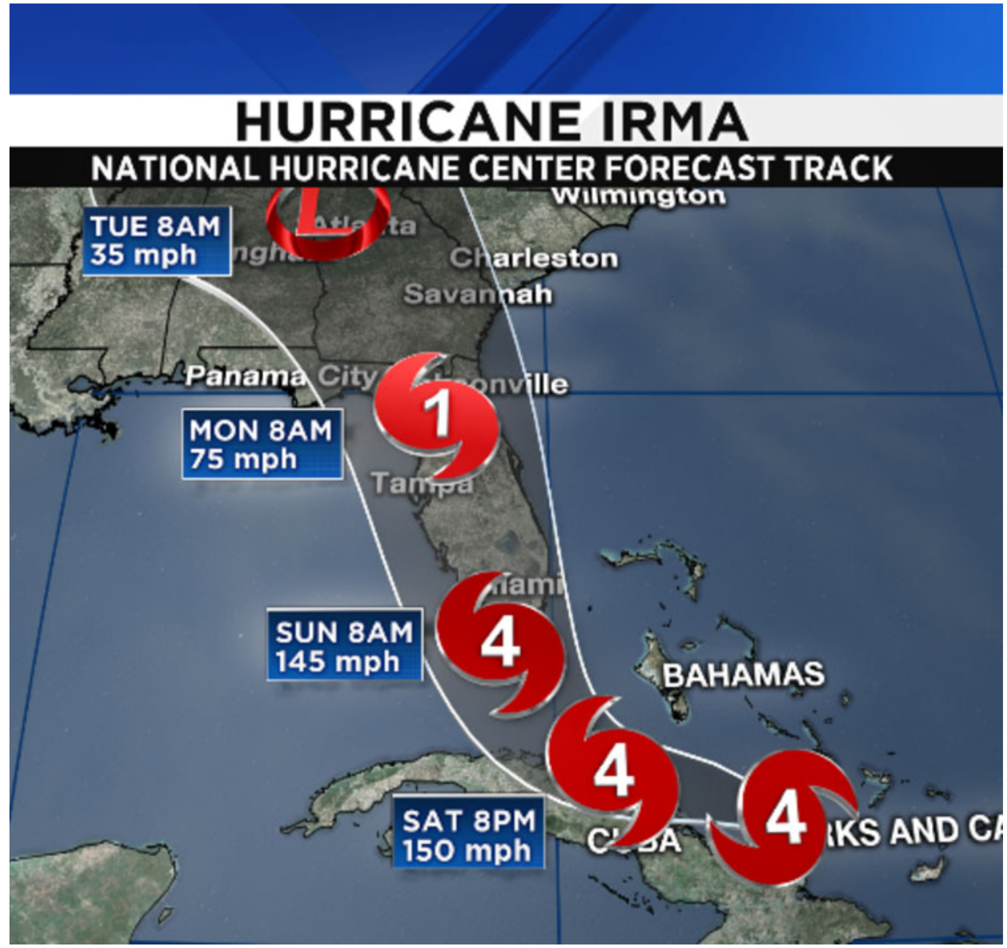
Herbicide Use – 10-year average



UF | IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

Hurricane Irma

- 2017 – massive disturbance
- Hydrilla was destroyed, didn't return
- Stakeholders believe contaminated sediment to blame for hydrilla failure to reestablish



UF IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

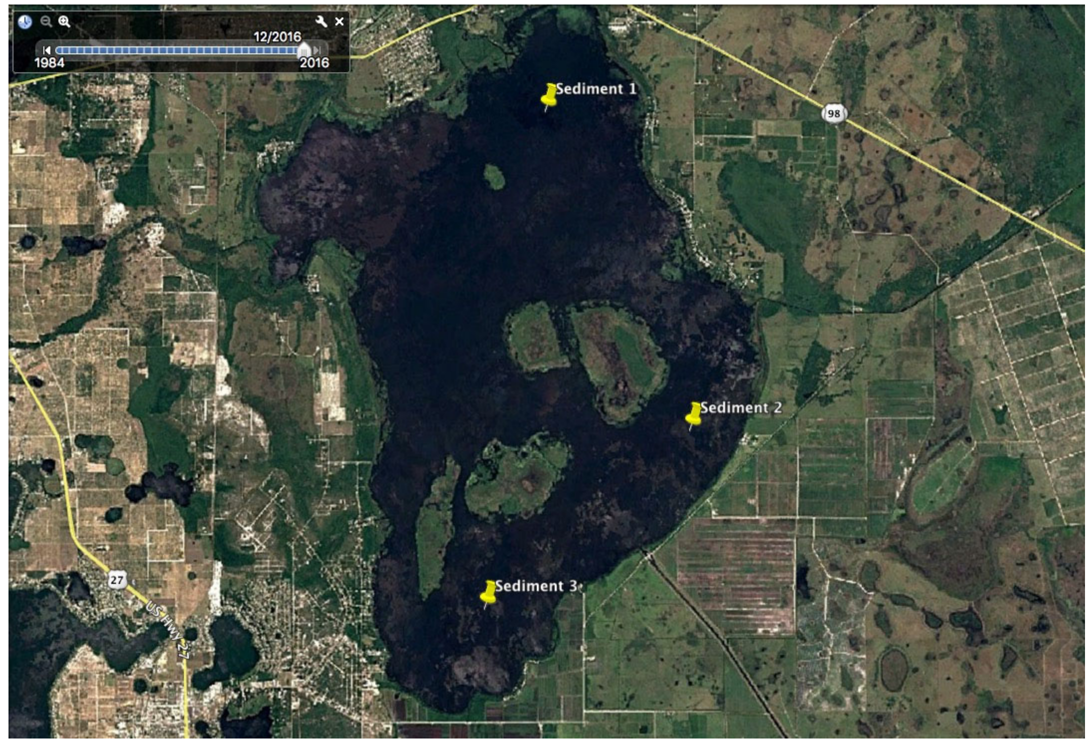
Lake Istokpoga Advisory Committee

- February 2019 – UF/IFAS Center for Aquatic and Invasive Plants became involved
- We recommended a 3-pronged approach
  1) Herbicide concentration in sediment study
  2) Bioassay sediment study
  3) Hydrilla tuber density study

UF|IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

Sampling locations

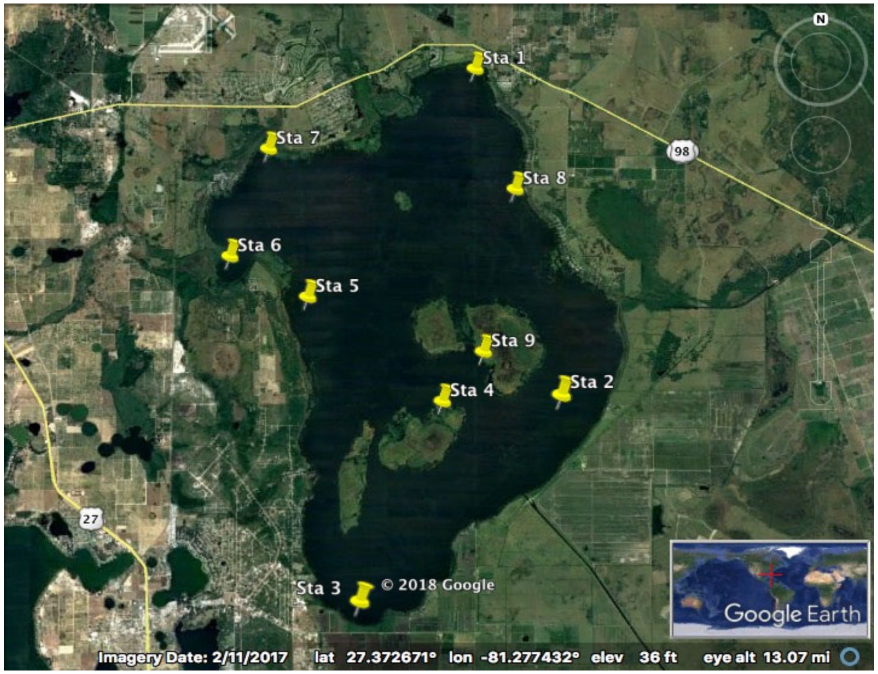
- We worked with the advisory committee to select 3 sites to sample at Istokpoga and Toho.



UF IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

Sampling locations

- After the initial selection, the council wanted more sites
- We started with 36 locations, but we negotiated down to 9
- Some projects have just 3 sites and others have all 9



UF IFAS UNIVERSITY of FLORIDA
CENTER FOR AQUATIC AND INVASIVE PLANTS

Lab analysis

- Samples taken at 9 spots
- Each sample was double bagged and stored on ice
- Shipped to a private lab

- Analyzed for 9 most commonly used herbicides on Lake Istok.

UF | IFAS UNIVERSITY of FLORIDA

CENTER FOR AQUATIC AND INVASIVE PLANTS

Bioassay

- Samples collected just as we did for the residue analysis
  - Members of advisory group were invited
- 5 gal of sediment from each station
- Sediment was de-watered and sifted

UF | IFAS
UNIVERSITY of FLORIDA
CENTER FOR AQUATIC AND INVASIVE PLANTS

Bioassay

- The 9 Istokpoga samples were compared with 3 locations from Lake Toho
- We included 2 controls – pure sand and sand + potting mix.
- Tomato seeds and hydrilla tubers used
  - 4 replications used

UF IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

Tuber sampling

- Original 3 locations were used
- 20 samples at each location
- Sampled every 30 m
- Samples sifted by hand and tubers identified by visual assessment

UF IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

Results

Analytical analysis

Analytical analysis

Herbicide	Concentration*	Limit of detection (ppb)
Flumioxazin	U	20
Glyphosate	U	50
Imazamox	U	10
Imazapyr	U	10
Penxosulam	U	10
2,4-D	U	50
Triclopyr	U	50
Diquat	U	2000

*U = undetected

No lab could run endothall

UNIVERSITY of FLORIDA

CENTER FOR AQUATIC AND INVASIVE PLANTS

Bioassay Sediment Results

Bioassay results – Round 1

Location	Tomato germ (%)
Istok -1	72 ± 20
Istok -2	23 ± 5
Istok -3	88 ± 9
Toho -1	52 ± 17
Toho -2	70 ± 23
Toho -3	65 ± 23
Control (sand)	95 ± 5
Control (sand + OM)	92 ± 5

- Averages

- Control – 94%
- Istokpoga – 61%
- Toho - 63%

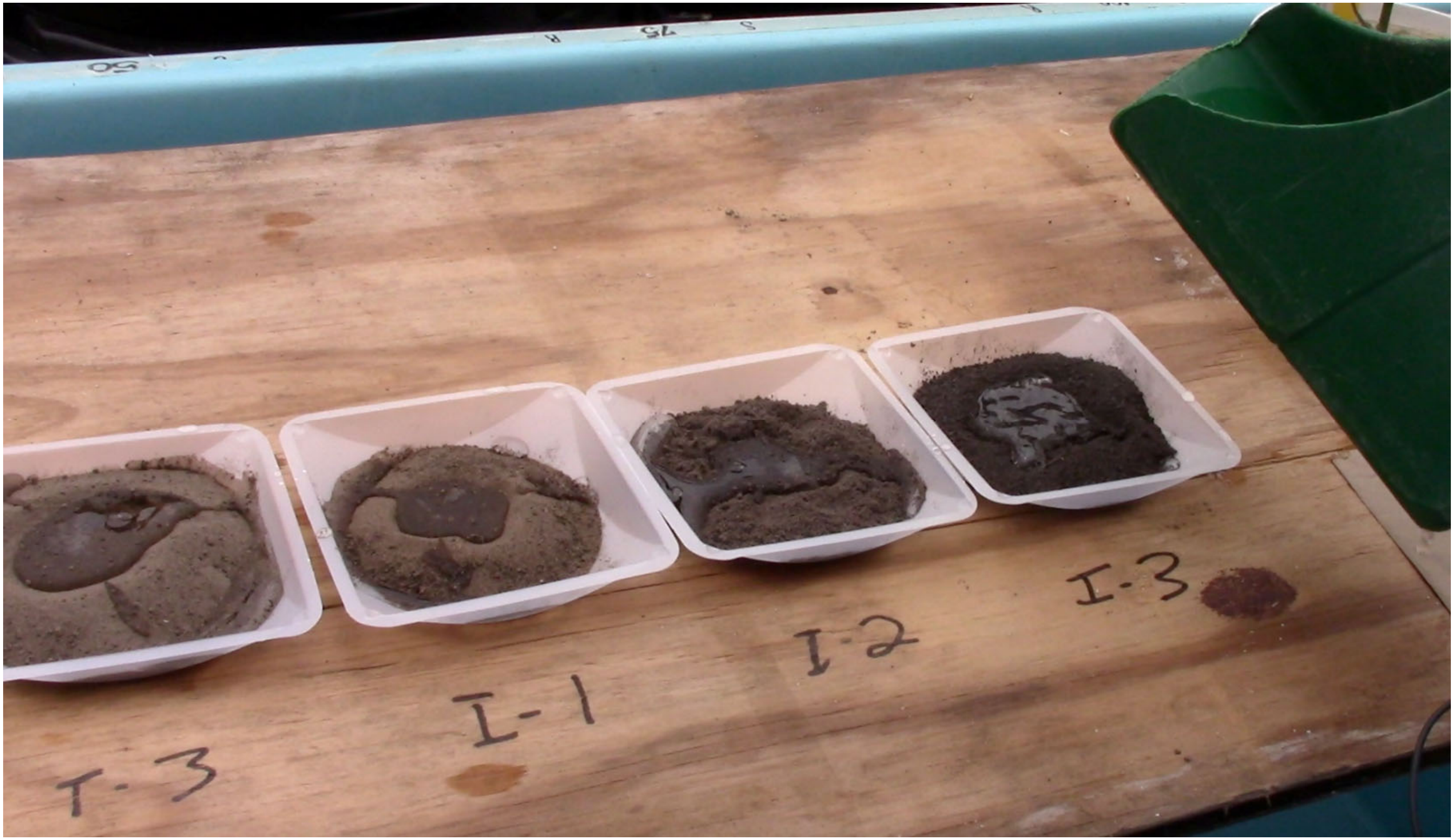
UF IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

Bioassay results – Round 1

Location	Tomato germ (%)	Tomato wt (g)
Istok -1	72 ± 20	1.1 ± 0.1
Istok -2	23 ± 5	1.2 ± 0.1
Istok -3	88 ± 9	1.5 ± 0.2
Toho -1	52 ± 17	0.3 ± 0.1
Toho -2	70 ± 23	0.5 ± 0.1
Toho -3	65 ± 23	0.7 ± 0.1
Control (sand)	95 ± 5	0.9 ± 0.2
Control (sand + OM)	92 ± 5	

UF IFAS UNIVERSITY of FLORIDA

CENTER FOR AQUATIC AND INVASIVE PLANTS


I-1
I-2
I-3

Bioassay results – Round 1

Location	Tomato germ (%)	Tomato wt (g)
Istok -1	72 ± 20	1.1 ± 0.1
Istok -2	23 ± 5	1.2 ± 0.1
Istok -3	88 ± 9	1.5 ± 0.2
Toho -1	52 ± 17	0.3 ± 0.1
Toho -2	70 ± 23	0.5 ± 0.1
Toho -3	65 ± 23	0.7 ± 0.1
Control (sand)	95 ± 5	0.9 ± 0.2
Control (sand + OM)	92 ± 5	

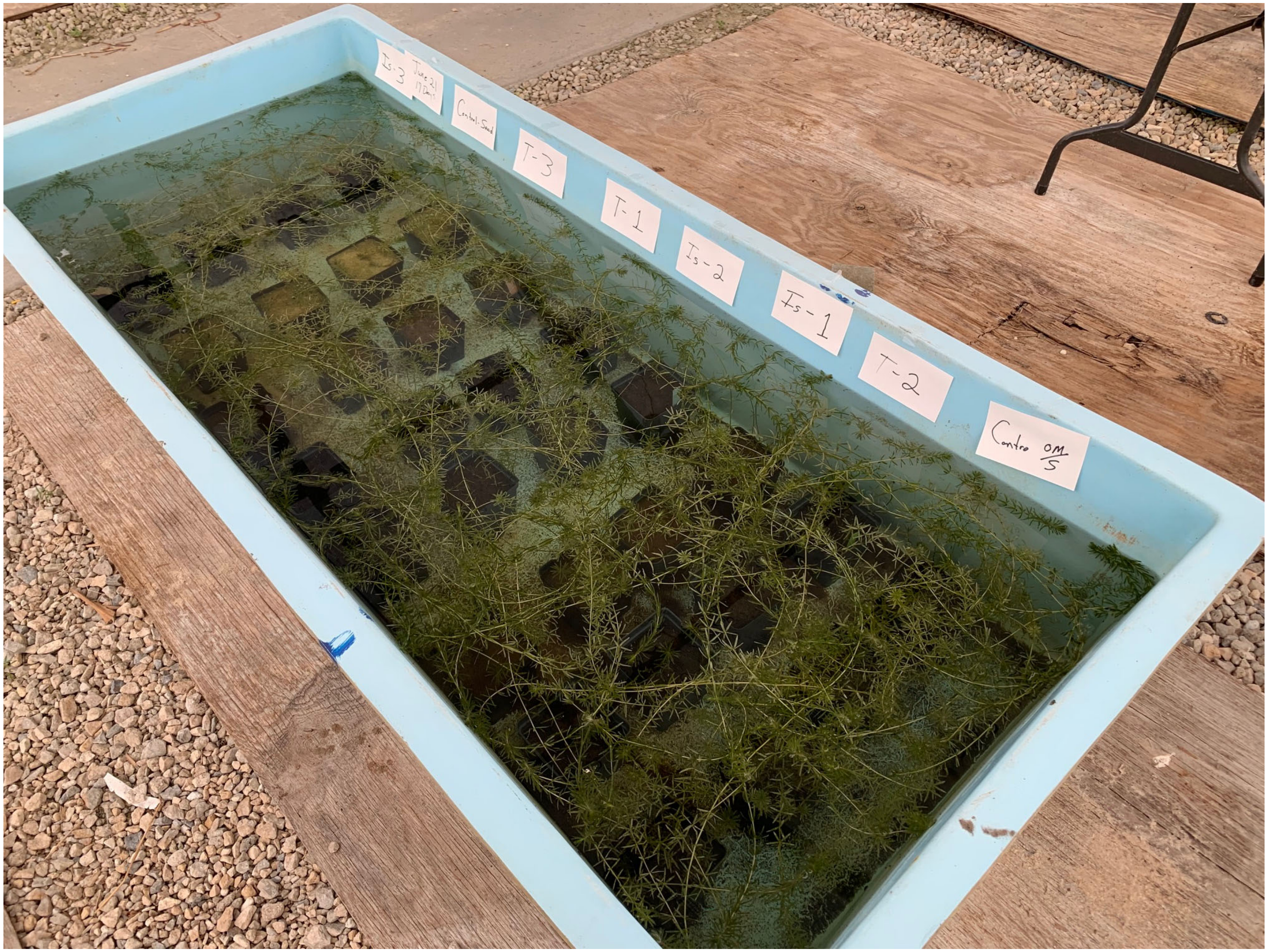
RSITY of FLORIDA IFAS

CENTER FOR AQUATIC AND INVASIVE PLANTS

Istokpoga: Bioassay Sediment Study

Bioassay results – Round 1

Location	Tomato germ (%)	Tomato wt (g)	Hydrilla germ (%)
Istok -1	72 ± 20	1.1 ± 0.1	79 ± 16
Istok -2	23 ± 5	1.2 ± 0.1	50 ± 13
Istok -3	88 ± 9	1.5 ± 0.2	48 ± 4
Toho -1	52 ± 17	0.3 ± 0.1	38 ± 20
Toho -2	70 ± 23	0.5 ± 0.1	38 ± 20
Toho -3	65 ± 23	0.7 ± 0.1	58 ± 16
Control (sand)	95 ± 5	0.9 ± 0.2	43 ± 8
Control (sand + OM)	92 ± 5		


T-3
T-1
Is-2
Is-1
T-2
Contro OM/S

Bioassay results – Round 2

Location	Tomato germ (%)	Tomato wt (g)	Hydrilla germ (%)
Istok -4	52 ± 22	-	-
Istok -5	82 ± 5	-	-
Istok -6	47 ± 32	-	-
Istok -7	40 ± 21	-	-
Istok -8	77 ± 15	-	-
Istok -9	27± 19	-	-
Control (sand + OM)	87± 9	-	-

UF IFAS UNIVERSITY of FLORIDA
CENTER FOR AQUATIC AND INVASIVE PLANTS

Bioassay Sediment Study Conclusions

- Tomato seeds planted in Lake Toho and Lake Istokpoga sediments germinated equally to each other, but less than seeds in control soils
- Tomato dry weight was similar between Control (sand) and Istok 1,2,3; weight in Toho sediment was less.
- Hydrilla tubers planted in Lake Toho and Lake Istokpoga sediments grew equally to those planted in control soils

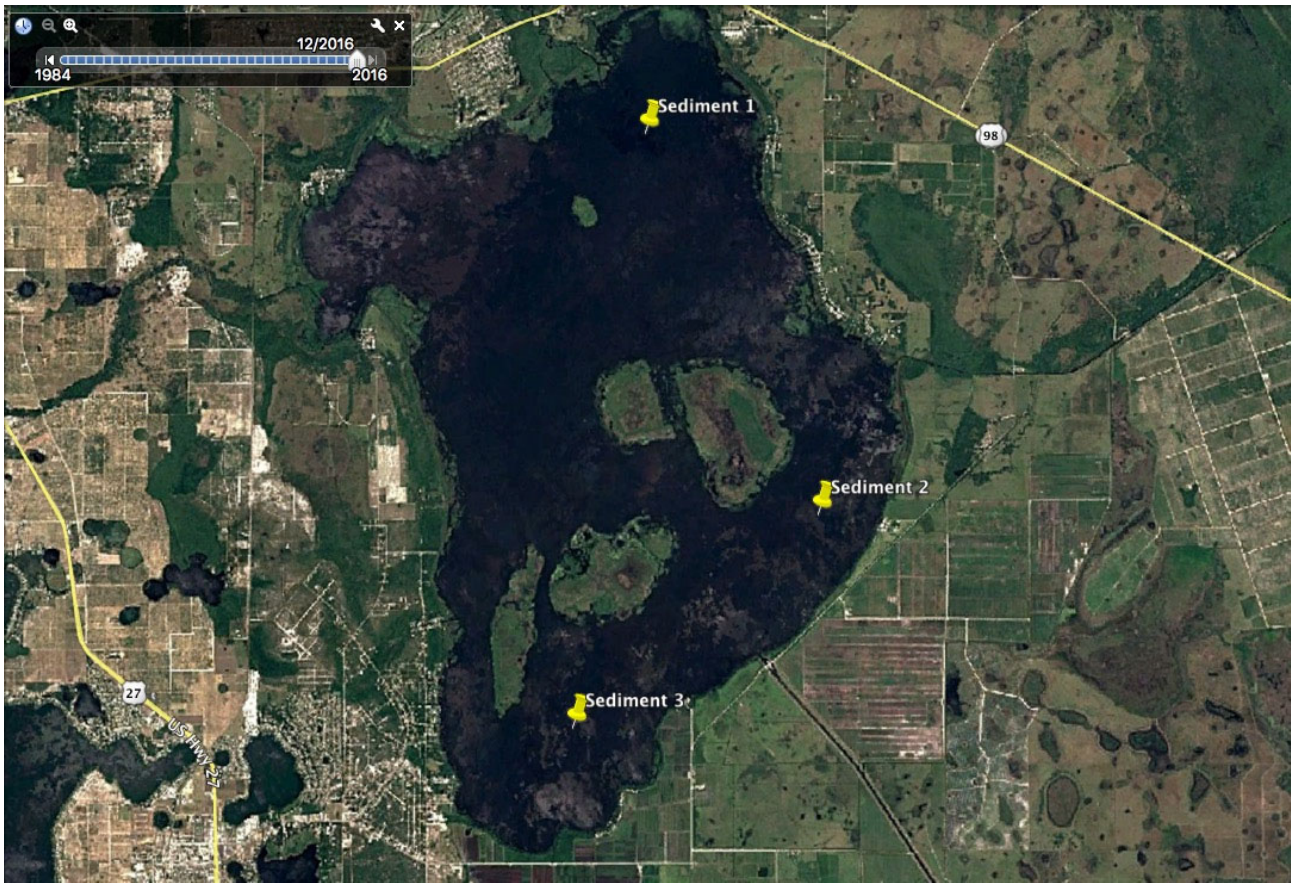
So what is going on?

- Lab can’t detect herbicides in the sediments
- Tomato and hydrilla don’t seem to detect herbicides

- Why is there no hydrilla in Lake Istokpoga?

UF IFAS UNIVERSITY of FLORIDA
CENTER FOR AQUATIC AND INVASIVE PLANTS

Search for tubers in original 3 locations



Tuber numbers

- Location 1 – 0
- Location 2 – 0
- Location 3 – 0

- 60 cores – no tubers
- Istokpoga once had 20,000+ acres and 200-300 tubers per square meter is common. Where did they go?

Where did it go? We don't know

- Similar things have happened on Lake Weohyakapka

- 1995 – 6000A hydrilla on a 7500A lake
- 2004 – 3 hurricanes passed over, hydrilla disappeared and has not returned

Science vs social science

- I know herbicides don't accumulate in sediment. So, was this all a waste of time?
- The loudest voices at the beginning became the strongest allies.

UF | IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

Shout-out to Dr. Bill Haller

So, why don’t these herbicides build up?

Herbicides in the Environment

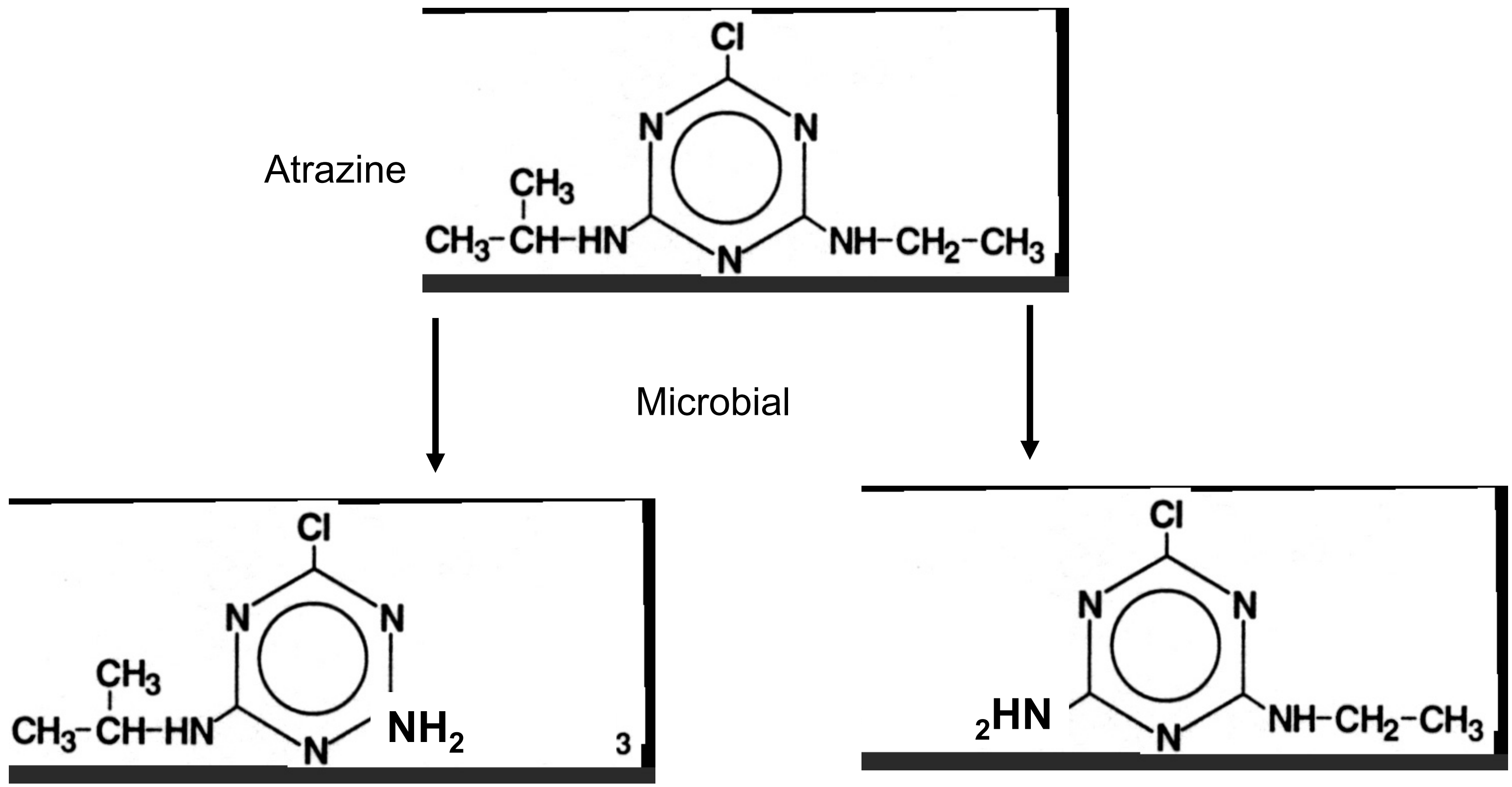
What happens to them??

Herbicide Degradation

- How are herbicides degraded?

- Microbes – bacteria or fungi chew it up.
- Water – hydrolysis, water breaks it
- Light – photolysis, light breaks it

Atrazine: First step in degradation



De-ethylatrazine

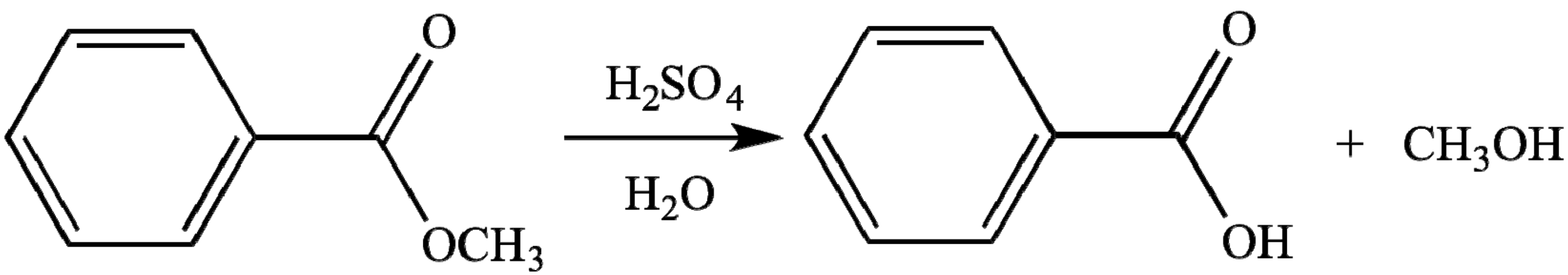
De-isopropylatrazine

Microbial degradation

- Endothall
  - Works best in winter months
  - Breaks down to glutamic acid, an amino acid

Hydrolysis

- When water pH drives breakdown



- Particularly important for flumioxazin
  - Half-life: 16h at pH 7, 0.3h at pH 9

UF IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

Photo-degradation

- Photolysis
  - Breakdown by sunlight

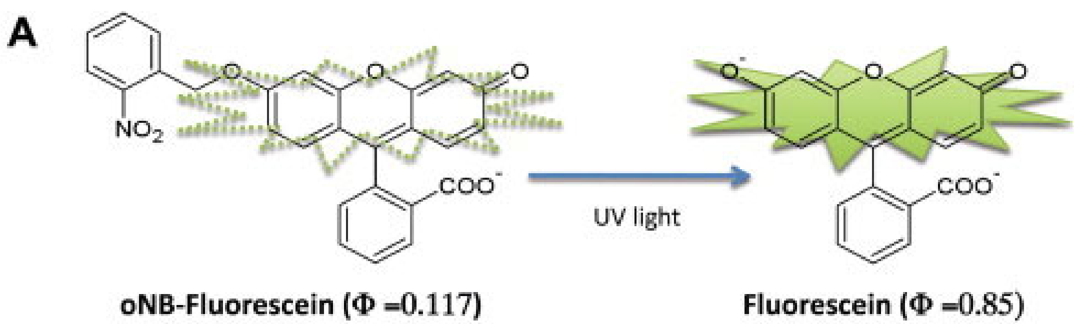


Photo-degradation

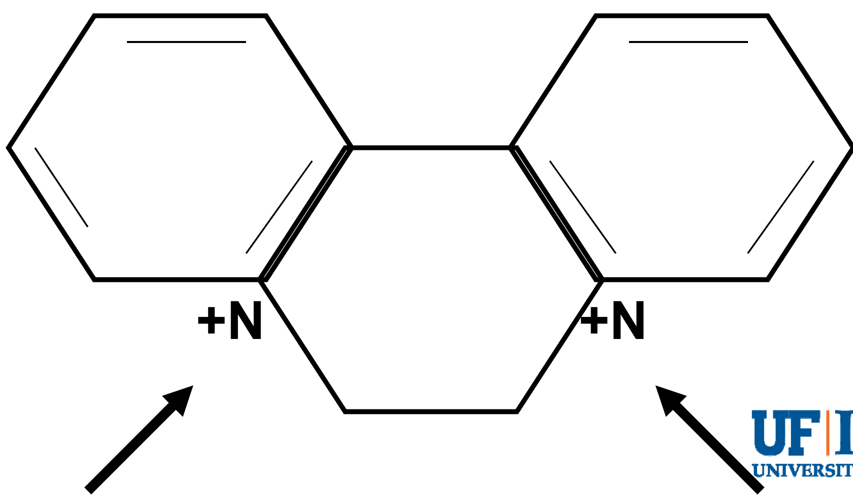
- Photolysis - Breakdown by sunlight

- Triclopyr
- Penoxsulam
- Imazamox
- Fluridone
- Diquat – to some degree

UF IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

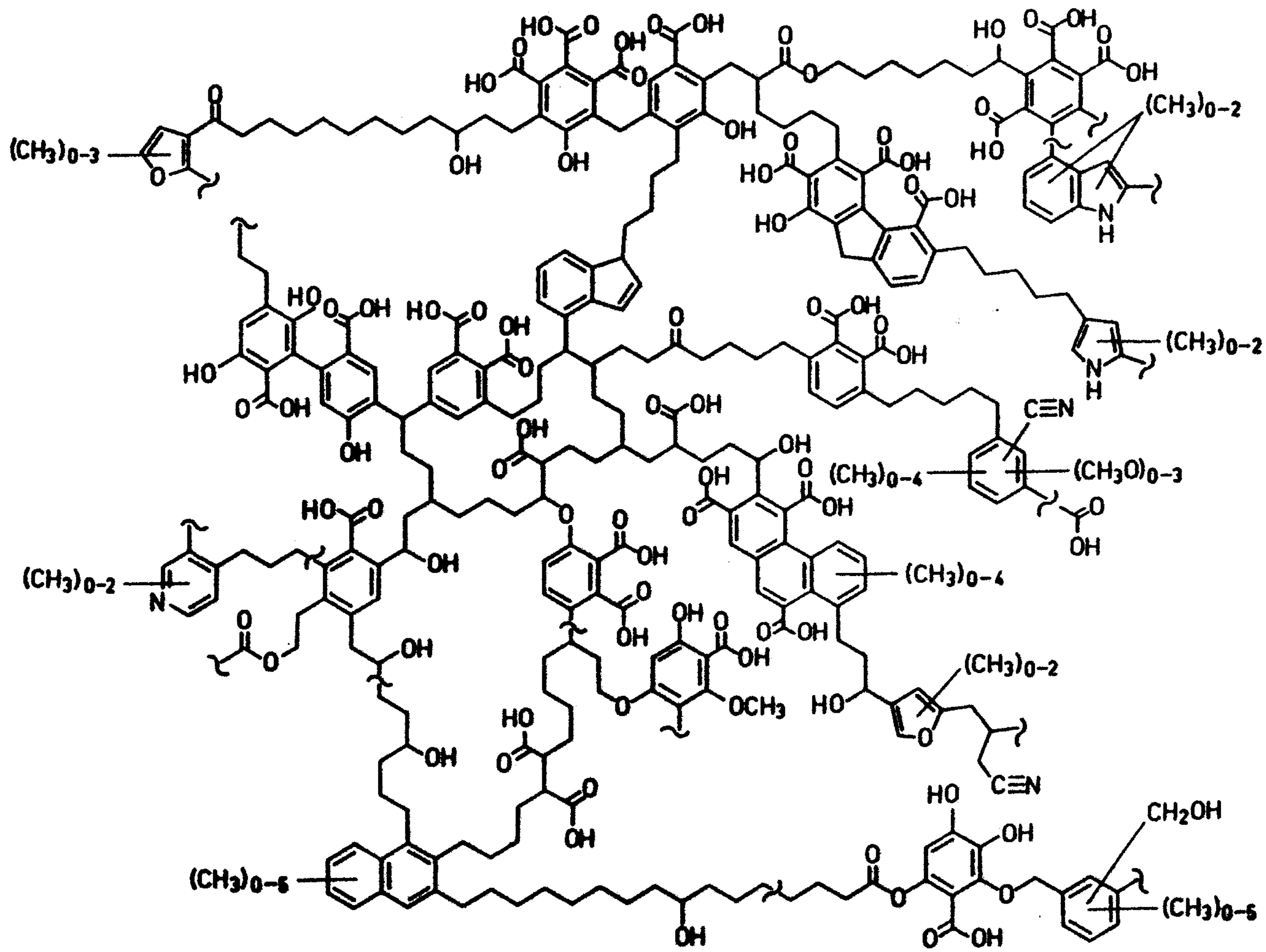
What Happens to Diquat?

- Breaks down from light and microbes
- Adsorption to soil or organic matter
  - Strongly sorbed, loves organic matter



UF IFAS UNIVERSITY of FLORIDA
CENTER FOR AQUATIC AND INVASIVE PLANTS

Herbicide adsorption



Diquat

- When it binds to OM, it never lets go
- This protects the molecule from light and microbes
  - Microbes will eventually get it, but is very slow

- But...it also keeps it from being available to plants.

Testing for Diquat

- Very difficult process.
  - Only one lab in US does this.
  - Only guarantees 60% recovery.
- How does it work?
  - Take sediment and add highly concentrated sulfuric acid. Heat and stir. When OM is completely destroyed, you can find diquat.

UF IFAS UNIVERSITY of FLORIDA | CENTER FOR AQUATIC AND INVASIVE PLANTS

But how do we know they won’t build up?

United States Environmental Protection Agency
Prevention, Pesticides And Toxic Substances (7101)
EPA 712-C-08-021
October 2008

Fate, Transport and Transformation Test Guidelines

OPPTS 835.6200 Aquatic (Sediment) Field Dissipation

United States Environmental Protection Agency
Prevention, Pesticides And Toxic Substances (7101)
EPA 712-C-08-018
EPA 712-C-08-019
October 2008

Fate, Transport and Transformation Test Guidelines

OPPTS 835.4300 Aerobic Aquatic Metabolism

OPPTS 835.4400 Anaerobic Aquatic Metabolism